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FUTURE GENERATION TACTICAL ENGAGEMENT SIMULATION

U.S. ARMY PRIORITIZED NEEDS AND RECOMMENDED SUPPORTING TECHNOLOGY DEVELOPMENT

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This report describes the results of a study to determine the U.S. Army prioritized needs for future generation tactical engagement simulation (TES) systems for the years 1995-2015. It also assesses the availability of technologies to meet the highest priority needs and describes and recommends technology development programs to ensure that the necessary technologies will be available when needed.

This report was prepared by the Jet Propulsion Laboratory for the U.S. Army Project Manager for Training Devices (PM TRADE) as part of the Simulation of Area Weapons Effects (SAWE) Project.

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FOREWORD

This report, prepared by the Jet Propulsion Laboratory (JPL) for the U.S. Army Project Manager for Training Devices (PM TRADE), describes the results of a study to determine and prioritize the needs for future generation Tactical Engagement Simulation (TES) systems, and to assess the availability of technologies to meet these needs. This work was performed as part of the Simulation of Area Weapons Effects (SAWE) project at JPL.

The views and opinions of the authors expressed in the report do not necessarily state or reflect those of any agency of the United States Government. Any comments, suggestions, or opinions may be addressed to the authors for consideration in future JPL studies.

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The major contributing authors to this report are Mr. Jon Inskeep (TES Task Manager), Mr. Warren Dowler, and Mr. Robert Beaudet.

Other contributors to this report were Mr. Gordon Wiker, Mr. Ned Ferraro, and Ms. Ann Griesel. Ms. Rosemary Hagerott edited and assembled the report.

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The authors gratefully acknowledge the guidance and support received from Mr. Joe Thompson (deceased) of PM TRADE who was instrumental in creating and nurturing this task.

PREFACE

This report is structured in the following manner. The full report consists of two volumes. This is Volume 1, the main body of the report. Section 1 provides an overview of the TES study and report. A summary of the JPL recommendations to the Army, which are the final results of the study, is presented as Section 2. Sections 3 and 4 give overviews of the methodology used to implement the study leading to these recommendations. Section 5 is a detailed discussion of the TES technology development programs recommended by JPL.

Volume 2 contains the appendices, which provide suppporting material on the methodology used in the study, the complete results of the Army responses on future generation TES needs and their priorities, and additional discussions on TES technology. The material in the appendices serves to support the conclusions and recommendations reached by JPL, and also provides a comprehensive and valuable database for any Army follow-on studies and development in future generation TES.

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VOLUME 1

ACRONYMS

AAR	After Action Review
AMC	Army Materiel Command
BTA	Best Technological Approach
CW	Chemical Warfare
GPS	Global Positioning System
JPL	Jet Propulsion Laboratory
MILES	Multiple Integrated Laser Engagement System
MWLD	Man-Worn Laser Detector
NTC	National Training Center
PM TRADE	Project Manager for Training Devices
PNS	Prioritized Needs Summary
SAG	Study Advisory Group
SAWE	Simulation of Area Weapons Effects
TES	Tactical Engagement Simulation
VLSI	Very Large Scale Integrated

SECTION 1

INTRODUCTION

The current generation Multiple Integrated Laser Engagement System (MILES) for simulation of direct fire weapons is based on 1960 laser technology; other components of MILES are based on technology that is more than ten years old. More recent technology has been used for tactical engagement simulation for helicopters and air defense; AGES II will have equipment that is based on current technology.

Army experience with MILES has been very positive and troop acceptance is high. But field experience has also revealed many areas for possible system improvements and, in particular, the need to consider new requirements such as precision gunnery, operation on the obscured battlefield, improved data gathering for After Action Reviews, and additional capability to simulate air defense engagements.

Technology advancements since the first fielding of MILES have already allowed many improvements to be made, such as those found in AGES II. Other new capabilities can be added as funding becomes available. However, the advanced technology of many new weapon systems, especially those expected to be on the battlefields of the years 1995 and beyond, creates a number of new simulation needs beyond the limits of available technology. The lack of maturity in many new technologies (which might support future generation TES needs) is such that they can make little contribution to the practical design of TES systems without further development.

1.1 SPONSOR

The Future Generation Tactical Engagement Simulation (TES) Task is part of the Simulation of Area Weapons Effects (SAWE) Project at the Jet Propulsion Laboratory (JPL) and is sponsored by the Project Manager for Training Devices (PM TRADE) of Orlando, Florida. PM TRADE is part of the U.S. Army Materiel Command (AMC).

1.2 PURPOSE OF THE FUTURE GENERATION TES STUDY

The purpose of this study is to ensure that the technologies needed for future generation Army TES training systems are identified and will be available when they are needed.

1.3 OBJECTIVE OF THIS REPORT

The objective of this report is to describe and recommend technology development programs that will be required to ensure the ability of the U.S. Army to field future tactical engagement simulation systems in the years 1995 and beyond. This includes the identification of the future TES needs, an assessment of which needs can be met with existing technology and which will require new developments in supporting technologies.

1.4 SCOPE OF TES STUDY

This study is limited to the technologies applicable to tactical engagement simulation for Army force-on-force maneuver training in the field. It is applicable to training of units from squad to battalion in size, both mounted and dismounted. Systems for training individual skills and training systems relying entirely on simulation (like ARTBASS) were not included. The study considered training and engagement simulation needs for the years 1995-2015.

The Army Statement of Work (see Appendix F) for this study required a system engineering study effort leading to a conceptual system-level Best Technological Approach (BTA) for future generation TES, in addition to identifying technological improvements and requirements. Shortly after beginning the study, JPL determined that a system-level BTA could not be conceived until several of the technologies supporting TES were developed further and their contribution to TES assessed. Therefore, agreement was reached with the sponsor to carry the recommendations in this study only through those for technology development; a BTA would be addressed in any follow-on work. JPL recommends that a system-level approach be taken to future generation TES with the objective of developing an integrated TES instrumentation system.

Because of the importance of After Action Reviews (AARs), which provide rapid feedback immediately after force-on-force field training exercises, instrumentation to collect, manipulate, and display data, which is essential to conduct adequate AARs, has been included as part of TES systems.

Although not within the scope of this study, significant comments on present generation MILES and Army training doctrine that JPL received during extensive interviews and questioning of combat forces, are summarized in Section 3 of Appendix A.

SECTION 2

SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS

2.1 TES OVERVIEW

The training benefits that can be achieved from force-on-force field exercises using Tactical Engagement Simulation (TES) systems in free play scenarios have been clearly and convincingly demonstrated at the U.S. Army National Training Center (NTC) at Ft. Irwin, California. At the same time, those who look past the initial euphoria of an NTC experience realize that many of the most devastating aspects of modern ground warfare are played only in a cursory manner or are entirely absent. These include artillery, mines (both conventional and FASCAM), precision tank and antitank gunnery, air defense, and electronic warfare, among others.

Coupled with the need to improve existing simulations will be the necessity to provide the capability for training with new weapon systems (some of them extremely complex and sophisticated) which will be coming on line in the years 1995 and beyond.

The learning experience in force-on-force maneuver training is very dependent on timely and meaningful After Action Reviews (AARs). There is room for considerable improvement in this area, which can be achieved by combining engagement simulation and instrumentation into a single integrated TES system.

Improvements can be made in many areas of TES without resorting to technology development programs and breakthroughs. Moreover, some problems with existing MILES are not technological or design problems at all; they are caused by shortcomings in Army policies or implementation as applied to TES and TES equipment. These are discussed further in this report in Section 3 of Appendix A.

The design of new and improved TES systems will draw heavily on the leading edge of modern technology. However, it is the conclusion of JPL, as the results of this study indicate, that many of the most significant needs of future generation TES systems will not and cannot be met with the technologies now available to the Army training community.

The subject of this study are those significant future generation TES needs that can be met if reasonable programs of technology development are begun now. These technologies could be placed into two categories: enabling technologies and implementing technologies. Enabling technologies are basic technologies that are being well supported by other agencies and programs, but are not sufficiently mature to be applicable to TES system designs. Implementing technologies are those technologies which are more mature and which have immediate potential for contribution to TES applications.

2.2 RECOMMENDATIONS FOR DEVELOPMENT OF IMPLEMENTING TECHNOLOGIES

JPL recommends that the Army initiate selected development programs now to ensure that necessary technologies for future TES systems are available when needed. Based on the results of the various phases of this study, the following programs should be initiated:

1. Laser and detector technologies for weapon-target pairing through obscuration.

2. Laser technologies for simulation of air defense systems.

3. Laser systems for simulation of the new directed energy weapons.

4. Data systems engineering and data management development for enhancement of AARs of field training exercises.

5. Systems engineering for embedding precision gunnery training in existing fire control computer systems.

6. Computer-generated imagery software development for gunnery and AAR data display in support of the new generation smart weapons.

Further descriptions of these programs are found in Section 5.

2.3 RECOMMENDATIONS FOR ENABLING TECHNOLOGIES TO BE MONITORED

There are other areas of needed technology development that are not feasible for support within the Army training budget because of the magnitude of the effort required. Much of this technology, however, is under active development as part of large on-going programs in government and private industry. Additional work by the Army training community would not make these technologies available any sooner for TES systems. JPL recommends that these technology programs be monitored regularly by the Army. When development has progressed sufficiently that TES programs can benefit, then these technologies should be implemented with Army training funding by conducting TES concept demonstrations of the technology. The technologies to be monitored are the following; they are discussed further in Section 5.

1. Very Large Scale Integrated (VLSI) circuit implementation.

2. Solid-state memory development.

3. Millimeter wave development and implementation.

4. High speed, real-time computer graphics and image processing software development.

5. Satellite-based navigation (position location) systems implementation.

6. Solid-state integrated microsensor development.

7. Fiber optics development and implementation.

2.4 OTHER STUDY RESULTS

Other significant products of this study included in this report are:

1. A set of trip reports (Section 2, Appendix A) that are a valuable data base of Army experience with TES.

2. The Prioritized Needs Summary Questionnaire (Section 2, Appendix B) with a summary of the responses from 23 Army commands, which is a comprehensive compendium of the Army priorities in TES.

3. A Structured Functional Analysis model for TES (Appendix C) which will be useful to the Army in the system engineering and development of future TES systems.

4. Notes on the current use of MILES (Section 3, Appendix A), as reported by hundreds of users in the Army training and combat communities, which address many possible improvements in the present use of TES.

5. The report of a JPL Workshop and a subsequent meeting on TES Technology (Sections 4 and 5, Appendix D) containing several suggestions and recommendations to the Army on TES which are worthy of careful consideration by training developers.

6. A report assessing the state of current technologies applicable to the problem of engagement pairing through obscuration on the training battlefield (Appendix E). The report includes JPL recommendations for development programs which could lead to a solution to this high priority need.

SECTION 3

APPROACH

3.1 ARMY STATEMENT OF WORK

On July 16, 1985, the Army Future Generation Tactical Engagement Simulation Training Study Advisory Group (SAG) held a meeting at Ft. Eustis, Virginia. Attending this meeting were personnel from ATSC, DCST, USAREUR, HQ FORSCOM, PM TRADE, HQ TRADOC, CAC, CDEC, and JPL. The purpose of the meeting was to develop a draft statement of work for the exploration of the state-of-the-art technologies available for future MILES for force-on-force tactical engagement simulation training. A draft statement of work was issued with the minutes of that meeting, and a final version was issued on September 10, 1985. A copy of this statement of work is included as Appendix F.

3.2 JPL IMPLEMENTATION

JPL used the Army statement of work to define the approach to the task, applying the same methodology used in the JPL Simulation of Area Weapons Effects (SAWE) indirect fire, conventional mines and nuclear/biological/chemical effects simulation programs. This approach was implemented by JPL in the following phases:

1. Meet with Army organizations to determine the needs of the Army in TES, using a prepared survey agenda. Discuss the current TES system performance (MILES) and perceived future needs with Army training and combat personnel worldwide. (See Appendix A)

2. Use the information from these discussions to prepare a Prioritized Needs Summary (PNS) questionnaire on needs and priorities for distribution to Army commands. Obtain responses from the Army to verify the importance of the needs that JPL received from Army trainers and combat troops during the survey meetings. Summarize and report the responses by type of organization. (See Appendix B)

3. Sort the prioritized TES needs from the PNS Questionnaire into recommended areas of technology assessment. Support this assessment with a Structured Functional Analysis (SFA) of Army weapon systems and corresponding TES systems. Reduce the size of the list by eliminating all lower priority areas and those which can be met with existing and available technology. Identify the technologies whose lack of availability could impact the implementation of the next generation TES systems. (See Appendix D)

4. Describe and recommend programs to address the lack of availability of these needed technologies. (See Section 5)

3.3 TES STUDY ADVISORY GROUP

The Army Study Advisory Group supporting this task included representatives from the following organizations:

1. PM TRADE, Orlando, Florida
2. FORSCOM Headquarters, Ft. McPherson, Georgia
3. CACTA, Ft. Leavenworth, Kansas
4. ATSC - TES, Ft. Eustis, Virginia
5. ATSC - DMD, Ft. Eustis, Virginia
6. USAREUR 7th Army Training Command, Grafenwohr, West Germany.

Periodic meetings of the Future Generation TES Study Advisory Group were held so JPL could report on the progress of the study and receive direction for subsequent work. SAG meetings were held on:

1. July 26, 1985
   Initial meeting, prior to JPL involvement.

2. March 25, 1986
   Discussed JPL precursor meeting with personnel at Ft. Hood.
   Discussed itinerary for visits to Army commands in Germany and CONUS.

3. September 30, 1986
   Reported on visits with Army personnel.
   Reviewed first draft of PNS questionnaire.

4. June 25, 1987
   Reviewed unsorted results of PNS questionnaire.
   Approved JPL method for sorting and editing responses.

5. December 8, 1987
   Review and approval by TES SAG of tabulation of PNS.
   Discussed priorities of technology development.

3.4 TES TECHNOLOGY WORKSHOP

To support this study, JPL held a TES Technology Workshop at the California Institute of Technology in April, 1987. At this workshop, JPL consultants familiar with Army systems were invited to comment on JPL-identified TES needs and the availability of technology to meet these needs. A follow-up meeting was held at JPL in April, 1988. At this meeting, the consultants who expressed the most interest in technology at the Workshop were asked to comment on the conclusions reached by the JPL staff on recommendations for technology development. A complete report of the workshop is included as Section 4 of Appendix D. The minutes of the follow-up session, along with an Addendum containing comments on technologies applicable to TES, can be found in Section 5 of Appendix D.

3.5 STUDY OF TECHNOLOGIES FOR PAIRING THROUGH OBSCURATION

At the direction of PM TRADE, JPL undertook a separate study to determine the status and availability of current technology for application to the Army need for weapon-target pairing in training engagements through obscuration (dust and fog oil screening smokes). This included an assessment of the White Papers received by PM TRADE in response to Pairing Through Obscuration MILES, presented at the NTC Industry Day in May, 1987. The final report of this study is included as Appendix E.

SECTION 4

METHODOLOGY

This study was accomplished in the following five phases. This methodology was the same as that used successfully by JPL in previous SAWE Project studies for simulation of the effects of indirect fire and mines effects simulator programs.

4.1 MEETINGS WITH ARMY COMMANDS

JPL held numerous meetings with representative Army commands throughout the U.S. At these meetings, JPL discussed with trainers and combat troops both current experience with MILES and anticipated needs for future generation TES for the years 1995-2015. Using the same format, more meetings were held with Army commands in Germany and with the leading suppliers of current TES systems. Reports of these meetings are included as Section 2 of Appendix A.

4.2 PREPARATION OF PNS QUESTIONNAIRE

Based on the information gathered in these meetings, JPL drafted a Prioritized Needs Summary (PNS) questionnaire for formal response by the Army. This was to ensure that what JPL had heard and interpreted as the Army TES needs was correct, and represented an Army consensus. This document listed 383 TES items in 37 categories for prioritization. These items spanned a broad range of issues including Army installations where TES must be usable, weapons platforms that must be instrumented, features that must be simulated, and some ancillary specification limits such as weight and power consumption. Army reviewers were asked to prioritize the TES items as *Mandatory, Recommended, Useful, Not Useful,* and *Undesirable.* A total of 135 individual responses from 23 Army commands was received by JPL. A sample of the questionnaire and a list of the responding organizations are included in Appendix B.

4.3 REDUCTION OF RESPONSES INTO THE PNS

The Army responses to the questionnaire were collated, averaged, and analyzed to prepare the PNS that identifies the Army priorities for future generation TES needs in the 37 categories.

The summarized results of the questionnaire follow; the complete results are given in a copy of the PNS Questionnaire with the Army responses and comments added (Section 2 of Appendix B).

Type of training: The primary objective of TES is to support maneuver training and was rated as *Mandatory*. Gunnery and crew skills were given *Recommended* priority for future systems. Surprisingly, command and control functions received low ratings.

Location of training: The TES system should be employable at numerous centers ranging from small home stations to major centers such as NTC. This system should be very beneficial for National Guard and reserve training. Partial or downgraded systems could be configured for the smaller installations.

Size of unit: The system should be designed primarily for squad up to battalion-level training.

Instrumented platforms: All front-line combat platforms should be instrumented. These include dismounted infantry, armored vehicles, and attack helicopters. Other platforms, such as unarmored vehicles, artillery, and scout helicopters, received a lower ranking.

Types of weapons to be instrumented: Essentially all attended weapon systems should be instrumented, with special emphasis on the tank, rifle, machine gun, and antitank weapons. Mines, hand grenades, and artillery received lower ratings.

Features of the weapon systems to be simulated: Only the most important features of weapons received *Mandatory* ranking for simulation. These included target acquisition, aiming and tracking, firing, and weapon and target signatures. Shoot-on-the-move and shooting at moving targets were the most important features to simulate for tank gunnery. Other effects such as wind, ranging, and ballistics were given *Recommended* priority. Whether the TES simulation system should be embedded into the actual weapon system received both enthusiastic support and strong disapproval. Thus this feature must be carefully reviewed before implementation.

Conventional mines: All the characteristics associated with breaching or countering mines were rated as *Recommended*.

Chemical warfare (CW): The use of individual protective gear and different MOPP levels were determined as *Mandatory* for future TES. Simulating CW attacks and decontamination received high support, but were not rated *Mandatory*.

Other elements: The simulation of division-level command and control elements, combat support, and casualty evacuation, etc., received mixed votes.

Cues: The use of actual flash/bang/smoke cues was rated as *Recommended* for direct fire weapons, artillery, and mines.

Physical specifications: The TES system should be very lightweight, use very little power, be reliable, and easy to install.

4.4 DETERMINATION OF AREAS FOR TECHNOLOGY DEVELOPMENT

Based on the compiled Army ratings, JPL assigned supporting technology priorities to each item in the PNS. JPL used rankings of *Highest, High, Priority, None,* and *Possible Negative Training* as priorities for assessing supporting TES technologies. (The complete results can be found in Section 2 of Appendix D.) Much of the technology required for future generation TES systems is available today and requires little or no development to be useful for new designs. JPL reviewed the technology issues to assess which of the needed technologies were, in the opinion of JPL and its consultants, currently mature and available to TES, and which would require further development to support future generation TES needs.

JPL gave 26 of the TES PNS items ratings of *Highest* and 125 ratings of *High*. Of the first group, 16 items should require no further technology development to support future TES. The remaining 10 items are the top priority TES issues from the Prioritized Needs Summary; they will require the development of new supporting technology to meet the needs in future generation TES systems:

1. TES systems for the crew-served ground weapon platform (D2*).
2. TES systems for the armored vehicle platform (D3).
3. TES systems for the attack helicopter platform (D8).
4. Simulation of tank/fighting vehicle weapons (E11).
5. Simulation of antitank guided missiles (E13).
6. Simulation of aiming and tracking smart weapons (F5).
7. Simulation of firing smart weapons (F6).
8. Replication of shoot-on-the-move tank gunnery (G1).
9. Replication of tank gunnery at moving targets (G2).
10. Interoperability with existing MILES (W1).

* Refers to item number in the PNS Questionnaire

Of the 125 TES items having ratings of *High,* 69 require technologies which JPL has identified as sufficiently mature to support the next generation of TES systems. The remaining 56 items would require the further development of technology and therefore become the second priority for TES technology issues.

A complete discussion of the technology issues, along with supporting justification for the prioritization, is found in Section 3 of Appendix D.

4.5 RECOMMENDATION FOR TECHNOLOGY DEVELOPMENT PROGRAMS

Structured functional analysis (SFA) of the TES functions and interfaces (see Appendix C) identified many functions of different simulations that used the same supporting technologies. The candidates for technology development programs described in subsection 4.4 were combined into the six technology development programs recommended to the Army by JPL for implementation. The scope of each program is described in Section 5 along with estimates of program sizes. An assessment of the risks in each program is also given.

SECTION 5

RECOMMENDED PROGRAMS

5.1 TECHNOLOGY DEVELOPMENT

There are six recommendations for the development of technologies to support the needs of future generation TES systems. Suggested programs to carry out these recommendations are described in the following subsections.

It is the JPL assessment that, unless these or equivalent research and development programs are initiated and supported by the Army training community, there is little chance that the most important needs of tactical engagement simulation for the years 1995 and beyond will be met.

Each recommended program is discussed in terms of purpose, objective, risk, and approach. To assist future Army planning efforts, JPL has made estimates of the magnitudes of the recommended technology development programs in terms of approximate program duration and estimated level-of-effort.

5.1.1 Laser and Supporting Technologies For Pairing Through Obscuration

There are several potential methods for solving the Army need to pair through obscuration (see Appendix E). The most promising solution is the use of eye-safe CO_2 lasers in combination with RF for the transmission of pairing data. Implementation of such a system could be achieved through development of commercial CO_2 laser technology for Army field use and, more particularly, advancement in current technology in the use of uncooled pyroelectric detectors. It should be possible to demonstrate a proof-of-concept system in a relatively short period of time.

PROGRAM PURPOSE: To reopen the investigation of current technologies which could solve the problem of pairing weapons and targets during training exercises conducted in obscuration by dust or smoke.

PROGRAM OBJECTIVE: To demonstrate a viable approach to pairing through obscuration with a proof-of-concept system.

RISK ASSESSMENT: There are several potentially viable solutions to the problem of pairing through obscuration. The probability of successful implementation of one of these approaches is high.

GENERAL APPROACH: Initially, several approaches should be examined in separate study programs. These approaches are described and recommended in the JPL report included as Appendix E. They include: the CO_2 laser with uncooled pyroelectric detectors, erbium glass lasers operating at 1.54 microns, and an uncoded CO_2 laser used in conjunction with an RF transmitter. As additional performance data is obtained, trade-offs can be developed which would lead to a recommendation for a best technological approach (BTA). The BTA can then be developed into a demonstration of a proof-of-concept. Specific programs are:

1. <u>CO_2 Lasers</u>. High quality sensitive detectors in the far infrared, 8-13 micron region, are limited to HgCdTe devices. These detectors require cooling to 77°K using liquified gases or small mechanical coolers, such as cryotips or Stirling coolers. They are very expensive and require frequent maintenance. Alternatively, pyroelectric detectors are relatively inexpensive, but electrically noisy and insensitive. The development of an appropriate pyroelectric detector for these applications would have major impact on the cost and feasibility of using CO_2 lasers in TES. All innovative ideas in this area should be supported. A re-examination of the current performance of CO_2 lasers in terms of power and stability, and of uncooled pyroelectric detector sensitivity and noise levels, could be completed in about six months with a four-person level-of-effort.

   A parallel study should consider the feasibility of using fiber optics to couple multiple target sensors to a single cooled detector. This study could be another six-month program with a six work-month level-of-effort.

   If the results of the studies warrant a breadboard system demonstration, this could be accomplished in approximately another 9-12 months, with a level-of-effort of about five work-years.

2. <u>1.54-micron Erbium Glass Laser</u>. Eye-safe laser rangefinders using this technology exist. Questions that need to be answered are: 1) what type of detector is best suited for this wavelength, and 2) for this laser/detector combination, what is the performance in typical TES battlefield obscurants of fog oil smoke and dust? The expected performance of such a system should be verified in a study that could be completed in about six months, at a level-of-effort of twelve work-months.

   A demonstration would consist of a field test of pairing at this wavelength through various conditions of battlefield smoke and dust. A limited test at a suitable location, such as Ft. Hunter-Liggett or NTC, should be feasible using existing (rangefinder) hardware. This could be accomplished with a program lasting about two months at a staffing level of three people.

3. Hybrid System. The most promising program is the use of eye-safe CO_2 lasers in conjunction with RF transmission of pairing data. Implementation of such a system requires further development of commercial CO_2 lasers to make them suitable for Army field use and, more particularly, advancement in current technology in the use of uncooled pyroelectric detectors. This concept is more fully described in Appendix E. Informal discussions with a potential developer indicate that a one-year program of about $500K should yield a fieldable demonstration system.

5.1.2 Laser Technologies For Simulation of Air Defense Systems

The simulation of air defense artillery cannot be accomplished adequately with the present MILES system. The two major shortcomings are meeting the wide field of view of air defense fire control systems, and the long engagement range (greater than 5 km) of air defense. One approach to achieving wide field of view is to use electronically scanned lasers. Extending range requires more powerful (eye safe) lasers and/or more sensitive detectors. Such development has a high priority to close the gaps in air defense simulation.

PROGRAM PURPOSE: To investigate laser technologies which are applicable to improved future TES systems for the simulation of air defense weapons which will be compatible with existing MILES.

PROGRAM OBJECTIVE: To demonstrate, with proof-of-concept components, laser pairing systems that have sufficient fields-of-view and operating range to simulate the performance of the latest Army air defense systems.

RISK ASSESSMENT: The chances of success for this program are very good. Several developers have started work on electronically scanned lasers which could provide the wide sighting pattern needed in the simulation of air defense fire control systems. Recent advances in laser development as well as new techniques for message coding should result in systems which achieve greater operating range while maintaining eye safety.

APPROACH: The initial phase of this program would be a determination of the functional requirements for the major air defense TES systems. These requirements would then be matched with on-going developments in laser technology, particularly those associated with scanning and increased operating range. This program has much commonality with the development of methods for laser pairing through obscurants; techniques for improving detector performance as an example. A best technological system approach would be developed. This could be accomplished with a two work-year effort over a period of one year.

If the recommended approach is acceptable to the Army, a proof-of-concept system could be assembled in one year with a three work-year level-of-effort plus procurements.

5.1.3 Laser Technologies For Simulating Directed Energy Weapons

The Army is expected to field directed energy weapons, down to the infantry level, by the end of the 1990s. Training in the employment of these weapons on the battlefield will have a high priority. It can be expected that MILES direct-fire lasers might do an adequate simulation. But the performance, use, and doctrine for directed energy weapons must be compared to TES capabilities to be sure that adequate simulation will be available when needed, i.e., a BTA developed.

PROGRAM PURPOSE: To determine the specific requirements for tactical engagement simulation of directed energy weapons on the training battlefield and to verify that the required technology is available to build such TES systems.

PROGRAM OBJECTIVE: To recommend a BTA for a TES system for the new Army directed energy weapons.

RISK ASSESSMENT: Preliminary discussions with Army weapons developers indicate that the required TES technologies are at hand. The chances for successful development of a feasible BTA are very high.

APPROACH: TES development for directed energy weapons must first concentrate on analysis of the doctrine for deployment and use of these weapons on the battlefield to determine the TES requirements for weapon simulation, cues, pairing, and casualty assessment. These requirements would then be matched to the capability of existing and developing TES technologies and systems (such as MILES). Finally, a BTA would be developed. Such a program could be accomplished with a level-of-effort of two work-years, over a period of 12-15 months.

5.1.4 Data Systems Engineering and Data Management Development for Enhancement of AARs

The integration of TES and field instrumentation into systems to gather and report data for the After Action Review (AAR) is not well developed or even well understood by the Army. There has been legitimate criticism of the data available and the ability to present it for AARs at the NTC; the status of AARs is even worse for exercises at home stations, which comprise the bulk of Army training. This problem cannot be solved by improved weapon/target engagement simulation alone. The definition of the TES system must include instrumentation that is integrated into an overall data gathering and reporting system. It will be necessary to determine realistic AAR data requirements and make recommendations to the Army on the application of future generation integrated TES systems that will improve AARs, and thus markedly improve the training benefit of field exercises for all levels of unit size. It is the judgment of JPL that the Army would be missing an opportunity to obtain an order of magnitude improvement in training if it fails to do this.

PROGRAM PURPOSE: To define instrumentation which will acquire maneuver and engagement data on the training battlefield as it evolves in time, will process and analyze this data to the appropriate resolution for the various unit levels, and will display this data for efficient and timely feedback in support of AARs.

PROGRAM OBJECTIVE: To provide the Army with a BTA for a cost-effective TES system that includes integrated instrumentation for collecting, summarizing, and displaying data in support of AARs from squad to multi-company-level training. In addition to its primary purpose of training at home stations or other small training areas, this system would be particularly useful for training of dismounted infantry units, such as at the JRTC.

RISK ASSESSMENT: This is rapidly evolving technology that is now being widely supported since it has uses in many military and commercial fields. The chances of successful application to TES needs in support of better AARs can be expected to be very high.

APPROACH:

1. Determine the minimum realistic data requirements to support AARs for training exercises and the candidate systems for presentation and display at all unit levels in the field.

2. Develop recommended approaches, for displaying AAR data in the field, which are concepts for dynamic, graphic presentation tools that support the commander's analysis and field presentations at the AAR. The result would be a demonstration of available off-the-shelf new technology, such as computer graphics, image enhancement, and digital video interactive.

Such a program could be completed in about 12 months with an approximate level-of-effort of four work-years. A field demonstration of representative system components could probably be done with an additional level-of-effort of two work-years and completion in 12 months.

Follow-on programs would determine the best integrated system-level approach for instrumenting the TES training battlefield at non-instrumented (i.e., non-NTC) training sites for exercises at company and lower levels. For example, the desired system could be passive, whereby each key player or vehicle has a data collection and storage device that records engagement and position location data internally. All required data could be played back into a centralized computer after the exercise. Then the data from all devices would be transferred, summarized, and displayed appropriately for the AAR. Data could be enhanced through filtering, correlation, histograms, and determination of statistics and trends. The system would include an instrumentation hierarchy that provided for distributed processing based on a selected unit size. For example, data could be collected and reported at a squad level instead of for each individual soldier. At the AAR, position would be displayed as an ever-changing area for the entire squad rather than the location of each individual soldier. Engagement results would be determined by the engagement system, independent of the instrumentation system.

5.1.5 Systems Engineering for Simulation of Precision Tank Gunnery

The inability to simulate precision tank gunnery is a shortfall in the Army's existing TES system (MILES). Not only is the technology currently available to do this, but several manufacturers offer systems that do an excellent job of simulating precision gunnery. The problem is the cost of these systems, up to ten times the cost of MILES. There is little chance that advancements in technology alone will make such systems affordable in the future. Most use complex electromechanical components, such as gyros, that are not going to be reduced in cost by an order of magnitude. These systems achieve their performance by replicating many functions already found in the fire control system of the weapon. Significant TES cost savings could be achieved by finding ways to use sophisticated combat equipment in a training mode. Such methods might result from a program of system engineering that supports TES requirements, such as making data generated within the weapon system available to TES. The Army should realize that a weapon system will be used a thousand times more during its lifetime for training than for combat. It may be undesirable to encumber a combat weapon with training functions; however, a potent weapon in the hands of a poorly trained operator will be destroyed by the enemy before it can become a factor on the modern battlefield.

PROGRAM PURPOSE: To investigate cost-effective methods of simulating precision tank gunnery (shoot-on-the-move, shoot at moving targets) in force-on-force field training; methods that are interoperable with existing MILES engagement systems.

PROGRAM OBJECTIVE: To provide a BTA for an engagement system that will realistically simulate precision tank gunnery and can be produced at a cost of under $25,000 per tank system.

RISK ASSESSMENT: The chances for success for this program are not good but the rewards would be high. Considerable effort has already been expended in a number of developments. Expensive systems like TWGSS will have very limited deployment. Cost effective systems like MILES provide unrealistic simulation, some degree of negative training, and perhaps even misleading results in the outcome of training engagements. The chances of success of this program will be very dependent on the Army's willingness to adapt or modify combat equipment, such as fire control systems, to provide capability in a training mode.

APPROACH: This program will basically be a systems engineering analysis of tank gunnery systems, with emphasis on the M1 tank system, to determine the feasibility and trade-offs between various methods of achieving realistic simulation of tank gunnery. Candidate systems must be low cost (~$25,000 per tank), make maximum use of existing fire control system hardware and software, be usable in force-on-force field training, and be interoperable with MILES. A BTA would be recommended for further development into a breadboard system. The analysis program would require at least one year with a level-of-effort of three work-years. The breadboard system demonstration would take about nine months to complete, with a level-of-effort of three work-years and some significant procurements.

5.1.6 Computer-Generated Imagery For Simulation of Smart Weapons and for AAR Data Display

Simulation of smart weapons, such as FOG-M and fire-and-forget missiles, on the training battlefield is expected to involve the use of sophisticated, high resolution, real-time computer imagery and graphics in the field. The application of such weapons on the training battlefield will be particularly sensitive as the size of units trained rise in echelon. Development of applicable supporting TES technologies is well underway and is being heavily financed by other fields. But there are some specific and unusual software needs for TES that will have to be developed with training system funds. The need for better, more usable, graphics displays for AARs will be supported by this same development.

PROGRAM PURPOSE: To investigate the application of the technology of computer-generated imagery to the TES needs in the simulation of the new generation of smart weapons on the training battlefield, as well as to provide more effective data presentation for AARs (see subsection 5.1.4).

PROGRAM OBJECTIVE: To recommend specific applications for state-of-the-art computer imaging techniques to TES needs. Examples are controls and displays for engagement training with smart weapons, simulation of intelligence gathering on notional units, simulation of remote sensor imagery, and presentation of battlefield data at AARs.

RISK ASSESSMENT: The cost and complexity of current systems, especially as they apply to Army field use, contribute to a significant factor of risk in this type of development for training applications. Overall, the chance of achieving some useful application for training needs is high, since this technology is evolving very rapidly.

APPROACH:

1. For smart weapons, the initial effort would be a definition of the general requirements for simulation on the training

battlefield; that is, what aspects of smart weapons operation are important to simulate, and to what level of fidelity must the simulation be carried. A BTA (or BTAs) would be developed from these requirements.

2. The Army's intention to broaden maneuver unit sizes on the training battlefield, whether the units are real or notional, has created new questions and concerns on possible future TES needs. Areas such as intelligence gathering by remote sensing were not included in the PNS questionnaire, so prioritization of this and similar needs must be done.

3. The use of new techniques in computer-generated imagery, such as three-dimensional pictorial imagery, would directly support the objectives of the recommendation given in subsection 5.1.4. Development in this area would begin after the definition of requirements for improvements in AARs and the determination of a BTA in the program of subsection 5.1.4.

   A program encompassing these studies would take about eighteen months at a level-of-effort of 4-5 work-years.

Table 5-1 presents a summary of the six recommended programs discussed above.

5.2 TECHNOLOGY MONITORING

JPL recommends that the following technologies be monitored by the Army for future application to TES needs. Development of each of these technologies is being heavily financed by the government, military, or private industry and each is advancing rapidly. Additional support work by the Army training community would have little impact on the progress of development at this time. It is more practical and cost effective to monitor and assess the progress in these areas until such time as it is possible to directly implement them into the designs of future TES systems.

5.2.1 Very Large Scale Integrated (VLSI) Circuit Implementation

The expanded application of VLSI circuitry to TES systems can be expected to result in training equipment which is smaller, lighter, and uses less power. Each of these attributes was given top priority in the Army responses on future generation TES system needs. In addition to the importance of making the next generation of MILES equipment smaller and lighter (see Army Comments, Section 3 of Appendix A), the ability to add sophistication to future TES systems will be dependent on a corresponding ability to keep component size and power demands from continuing to grow. This will be particularly important in TES applications for dismounted infantry and for small, distributed TES systems for home stations training areas. Even in vehicular systems, smaller size will be necessary if TES is to be included in embedded systems.

Table 5-1. Recommended Programs Summary

	APPROXIMATE DURATION	ESTIMATED LEVEL-OF-EFFORT
1. Laser and Supporting Technologies for Pairing Through Obscuration		
a. CO_2 Lasers		
Re-examination	6 months	2 work-years
Fiber optics	6 months	1/2 work-year
Demonstration	12 months	5 work-years
b. 1.54-micron Erbium Glass Laser		
Performance verification	6 months	1 work-year
Demonstration	2 months	1/2 work-year
c. Hybrid System		
Proof-of-concept	12 months	(contract)
2. Laser Technologies for Simulation of Air Defense Systems		
Requirements	6 months	1 work-year
BTA	6 months	1 work-year
Demonstration	12 months	3 work-years
3. Laser Technologies for Simulating Directed Energy Weapons		
Requirements	6 months	1/2 work-year
Technology assessment	6 months	1 work-year
BTA	3 months	1/2 work-year
4. Data Systems Engineering and Data Management Development for Enhancement of AARs		
Requirements	6 months	1 work-year
System approach	6 months	1 work-year
System technology	6 months	2 work-years
Demonstration	12 months	2 work-years
5. Systems Engineering for Simulation of Precision Tank Gunnery		
Analysis	12 months	3 work-years
Demonstration	12 months	3 work-years
6. Computer-Generated Imagery for Simulation of Smart Weapons and for AAR Data Display		
BTA	6 months	1 work-year
PNS	6 months	1/2 work-year
Development	12 months	3 work-years

5.2.2 Solid-state Memory Development

Along with VLSI circuitry, the use of solid-state memory technology will contribute to smaller, more capable TES systems. One example would be distributed systems in which each player carries sufficient instrumentation to accomplish engagement pairing, real-time casualty assessment, and storage of pertinent results for post-exercise analysis to support AARs. Such systems would not need a central computer, telemetry of data, or the other capabilities of an instrumented range. The ability to use small, dense, solid-state memory would make it feasible to provide a three-dimensional position location data base on individual platforms or players. This could open up new concepts in accomplishing engagement pairing and casualty assessment, as well as practical methods of upgrading TES capabilities at non-instrumented home station training areas.

5.2.3 Millimeter-wave Development and Implementation

The concept of using millimeter-wave radar to accomplish engagement pairing between a weapon and a target in training exercises has been studied by the Army, most recently by the Harry Diamond Laboratory, for pairing through obscuration from dust and training smokes. This work was performed for the TRADOC Intervisibility and Obscuration Instrumentation Committee in 1985. A breadboard system was tested, but no further work was done because the system components were too large, expensive, and fragile to have immediate potential for fielded systems.

Millimeter-wave technology is being strongly supported by weapons development programs and advances in hardware designs show considerable potential for future TES applications. As cost and size of millimeter-wave components come down, and weapon system applications demonstrate reliable field performance, the use of millimeter-wave to augment laser pairing systems for training should be investigated once again. In addition to the ability to pair through obscurants, millimeter-wave technology has potential application for simulators of designators and rangefinders which are eyesafe and thus suitable for training.

5.2.4 High Speed, Real-time Computer Graphics and Image Processing Software Development

The rapidly advancing technology in this area will have potential application in a number of areas of future generation TES. Immediate contribution to the simulation of smart weapons, and the presentation of exercise data for AARs, is described in subsection 5.1.2. Other possible applications for advanced computer graphics and imagery are in low-cost methods for the simulation of precision tank gunnery, the addition of more command and control functions into training exercises, and the ability to use realistic notional forces in the simulation of supporting elements.

5.2.5 Satellite-based Navigation (Position Location) Systems Implementation

When the Global Positioning System (GPS) becomes more fully implemented (precise round-the-clock operation and miniature receiving units), it will have great impact on future TES systems. Position location data is essential for managing the training battlefield during an exercise and for supporting AARs. Only a few Army training or test areas now have this capability, namely the NTC at Ft. Irwin, CDEC at Ft. Hunter-Liggett, and TCATA at Ft. Hood. GPS will add the capability to any training area where the players are equipped with GPS receivers.

There is a possibility that the availability of GPS on the training battlefield will revolutionize future TES systems. If the exact location of each player is known at the player, there is the possibility that engagement pairing can be accomplished by on-board computers knowing the location of weapons and targets without the need for communication channels such as the present MILES lasers. The problem of simulation of non-line-of-sight engagements with smart weapons might be similarly solved.

GPS on the training battlefield might also allow the use of sub-architectures in TES systems to track and report the area locations of squads or platoons rather than each individual, thus reducing data storage requirements for the support of AARs.

5.2.6 Solid-state Integrated Microsensor Development

Research in solid-state electronics and optics is yielding new materials and fabrication methods in diverse areas, many of which have potential applications in future TES systems. Band gap engineering, through molecular beam epitaxy and chemical vapor deposition, might result in a new generation of laser emitters and detectors. Monolithic microwave integrated circuit technology is being developed for new weapons systems. Large scale production for such applications would make TES applications in millimeter-wave pairing systems feasible. Integration of on-board solid-state sensors with micro-chip electronics, made possible by advances in micro-machining, can lead to improvements in future TES systems in terms of increased capabilities, lower costs, and smaller size and power requirements. New surface acoustic wave techniques have potential application for small, inexpensive detectors for chemical vapors.

5.2.7 Fiber Optics Development and Implementation

The application of advanced fiber optics technology offers the potential of improvement in engagement detector and TES communication systems. Examples are the use of distributed detectors on vehicles and the possibility of weaving continuous detectors into garments for infantry. Fiber optics data links might be used to communicate among crews and troops within vehicles to assess attrition on board vehicles.

Fiber optics, in combination with computer-generated imagery, has potential application to the problem of simulating some of the functions of precision tank gunnery, particularly targets and bursts in the sight picture.

Fiber optic sensors are currently being used in the development of transducers for the sensing and measurement of a number of physical parameters, such as pressure, position, orientation, and chemical concentration. There is considerable potential here for TES applications.

More complete discussions of these new technologies are contained in Section 5 of Appendix D (pages 175-195).